Network load based analysis of blocking probability in WDM Network

A Thesis submitted in partial fulfilment

Of the Requirements for the degree of

Master of Technology
In
Electronics and Communication Engineering
Specialization: Communication and Networks

By

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Under the guidance of
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June 2015

Dedicated to...

My Dear Friends

My Mom and Brother

Dept. of Electronics and Communication Engineering
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Rourkela-769 008, Odisha, India.

Certificate

This is to certify that the work in the thesis entitled *Network load based analysis of blocking probability in WDM Network* by Aditya Y Sukhadeve is a record of an original research work carried out by him during 2014 - 2015 under my supervision and guidance in partial fulfilment of the requirements for the award of the degree of Master of Technology in Electronics and Communication Engineering (Communication and Networks), National Institute of Technology, Rourkela. Neither this thesis nor any part of it has been submitted for any degree or diploma elsewhere.

Place: NIT Rourkela
Date: June 2015

Prof. (Dr.) Santos Kumar Das
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Abstract

Arrangement of expansible quality of service (QoS) attestation on wavelength division multiplexing (WDM) is a crucial and perplexing problem of the cutting threshold internet. From the essential performance parameters the blocking probability (BP) computation is a QoS adept in WDM network. This method of BP computation in a wavelength routed optical network (WRON) is presented, keep in mind that blocking-probability computation used only to a network that is remain same where, traffic demands arrive, wait for a convinced time, and finally dispense, so that the total traffic intensity for a time is same i.e. remain unchanged. For an active optical network (AON), despite the fact we lag behind that traffic loads will reach, wait for a fixed time, and afterword dispense, same we taken into account that the normalized intensity of traffic existing of a network is going to increase gradually with time as the number of users receiving on the typical network and also growth in their networking essentials towards large bandwidth uses, extended holding time uses, etc. Hence, blocking probability computation try not to use meanwhile traffic is not fixed. Otherwise, we have to take into account of "exhaustion probability," having a time duration, lastly we anticipated that the network is to run into capacity exhaust.

The realisation traffic distribution of network performs to achieve an exact blocking performance. So the BP for each available link having a shortest path or having a large weight in a sorted order taken into account, in the network the connection and node relation for the traffic between each link is dependant. The usefulness of this technique is to be applicable in low load region, exact, faster compare to other techniques. Furthermore, this technique is more useful to calculate the estimation of blocking probability per node as well as for the network.

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Abbreviations

QoS	Quality of service.
WDM	Wavelength division multiplexing.
DWDM	Dense wavelength division multiplexing.
BP	Blocking probability.
WRON	Wavelength routed optical network.
AON	Active optical network.
RWA	Routing and wavelength assignment.
OXC	Optical cross connection.
OADM	Optical add drop multiplexed.
SD	Source destination pair.
QoT	Quality of transmission.
IMM	Iterative matrix methodology.
DRCL	Distributed relative capacity loss.
RF	Radio frequency.
ISI	Inter-symbol interference.
TDM	Time division multiplexing.
FDM	Frequency division multiplexing.
SLE	Static light-path establishment.
DLE	Dynamic light-path establishment.
WA	Wavelength assignment.
FR	Fixed routing.
FAR	Fixed alternate routing.
AR	Adaptive routing.
FF	First Fit.
RF	Random Fit.
MU/LU	Most used / Least used
VoIP	Video over internet protocol.
SP	Shortest path.
AP	Access point.
NSFNet	National science foundation network.
DFS	Depth search algorithm.

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1.

INTRODUCTION

WDM is a technique where the number of wavelengths transmitted different data streams through the same channel simultaneously. Therefore, this network provides output speed in the ranges of Terabytes per seconds (Tbps), so that we can call this network to be flawless solution for the perpetually developing requests for higher bandwidth. The blocking probability is the basic performance parameter used for the estimation. Performance metric of WRON in distinctive scenarios. In the optical network calculating the precise hypothetical blocking probability it become very hard because of various parameter which are varying traffic load for the particular link or connection and it relies on other factors too such as multiple wavelength and the different network topology [4, 7, 8, 9, 10, 11]. For calculating the BP in WRON an estimated model is given, in this link blocking events are self-determining [8, 10, 11]. These models decrease the time complication, as well as decrease accuracy. So, several present models taken into consideration that related to blocking, which can perfectly estimate by the blocking performance of WRON. Number of techniques considers the reliance only adjacent links or path to decrease the required time to calculate it i.e. time complexity but for the one parameter the other parameter gets affected which accuracy so the additional links should allow the link restriction for their adjacent links so increased in the large time complexity. So we have to deal with complexity and the accuracy [4, 6]. Therefore, this is a basic area of research and development for the industry and the growing network in the world [1].

1.1 Motivation

Utmost WDM network works on the circuit switching principle for the interchange of collected traffic between nodes and also of the links. This active optical network processes the network performance by calculating the BP. It mainly centred on RWA technique to a given WDM network in demand of optimising the network performance.

Wavelength routed optical networks (WRON) is different than conventional electrically optical switching networks. It increases the throughput of the network as well as good communication for lengthy distance and it is cost proficient technique [2]. Communication in this network, such as optical cross-connects (OXC) and optical add-drop multiplexed (OADM) which are interrelated through fiber connections by number of wavelengths. The foundation of WDM network is depend on light-path available for requesting a connection. For a new connection request we need to know the RWA scheme to create a

light-path for a source destination (SD) pair. When there is no availability of connection for a SD pair, the connection request can be blocked [3]. So, the blocking probability is the basic performance parameter used for the estimation.

Techniques and strategies for estimating the BP in WRON have been seen network analysis. The direct impact on network matrix can be classified according to networks parameter used in the given technique. The traffic profile (traffic matrix) of any network depends on the certain parameters which are very essential while estimating the various performance parameters and network topology, For the estimation of BP we are taking into consideration some factors which is a function of traffic characteristics, wavelength conversion capability, different wavelength assignment strategies, routing techniques, placement of wavelength converters, and the last which is a more important than the others is a quality of transmission (QoT) of all the light-paths. The WDM is nothing but a assigning the same wavelength to all possible links beside the a path in the network and when there is assignment of wavelength of wavelength before that the wavelength conversion is done in the node if there is no conversion then a random wavelength conversion strategy is used which is the most important part of computing the BP by using the analytical models in the WRON [12]. By using the random wavelength assignment most part of methods had calculate the BP and also the other technique is First fit wavelength assignment which is least use than the random wavelength assignment. By using the random wavelength assignment most part of methods had calculate the BP and also the other technique is First fit wavelength assignment which is least use than the random wavelength assignment [4, 7, 8, 10, 11]. For calculating the BP analytical models by first-fit wavelength assignment for that the QoT of the light paths main parameter used in transmission moderated optical networks. The decreasing BP depends on the usage of full range wavelength converter or limited range wavelength converter because of wavelength continuity constraint. Some technique prove that the blocking performance by the use of limited range wavelength converters is very proficient of converting to a insignificant number of adjacent wavelengths estimate thoroughly that of full-range wavelength converters. Hence, another aspect is placement of wavelength converters which is crucial in the optical network for computing blocking performance

1.2 Literature Review

M.E. Houmaidi, M.A.Bassiouni, [4] Here they present how to compute the blocking probability for the given network topology which is totally depends on the link dependencies in all optical WDM networks for a constant traffic and by changing the number of wavelengths for a same network the change in the blocking probability can be calculated for a different traffic load. Computation of route blocking can be more precisely the adjacency and the connectivity of the routes of a nodes in a network can reflect their impact on traffic carried by each path.

R. Ramamurthy, B.Mukherjee, [5] This paper describe the formation of WDM connection between different source and destination pairs for the wavelength routing cross connects. If there is no conversion of wavelength, a connection is forced to on same wavelength channel along the route. The other routing technique can improve the performance of a network along with the improving blocking probability by allowing the different number of available paths among the source destination pair.

Y. Zhu, G. N. Rouskas, H. G. Perros, [6] The various class of circuit switched wavelength routing network with a different routing techniques such as fixed routing technique and alternate routing technique with random allocation of a wavelength. An iterative path decomposition algorithm to compute precisely and effectively the enactment of blocking using wavelength converters and without wavelength converters. In this paper examine the network in a single path subsystem by decomposing by the use of iterative method. For a complex problem of estimating call blocking probability in a wavelength routing networks this is an easy and computationally effective method

K. Lu, G. Xiao, I. Chlamtac, [7] The most important technique of distributed wavelength providing for helping the future generation wavelength routed network. The conversion of wavelength is done only at the subsection of network nodes which is also known partial wavelength conversion for a dispersed wavelength providing. The results of the simulation shows that for different network topologies for different traffic load the given model is accurate and precise.

Luiz H. Bonani, Iguatemi E.Fonseca, [13] The Iterative matrix methodology (IMM) Is used in this paper to calculate the blocking probability this is a iterative method that totally depends on the preciseness of the network traffic distribution for an exact blocking parameter. And finally

he compares the analytical results and this IMM results from which we can say that the IMM technique is faster than the conventional mathematical model and accurate too.

A. Birman, [11] A comprehensive reduced load estimate scheme is used to compute the blocking probability in this technique all the class of optical network is taken into consideration using the WDM and wavelength routing in which a route for a given SD pair providing a path and a wavelength in this paper they used two routing schemes which is fixed routing and least loaded routing..

H. Zang, J.P.Jue, B.Mukherjee, [12] The light-path between the SD pair set up by the number of requesting a connection between that SD pair and among all these available route, one route should occupies the same wavelength for all of the links which are present in the network for setting up a light path at least one path is selected and a wavelength is allocated. For a given light path if a wavelength is not available then the request is blocked for this blocking technique a new method is proposed by the author which is "Distributed Relative Capacity Loss (DRCL)" which is wavelength assignment strategy which mainly works in the distributed controlled networks.

1.3 Overview of thesis

The entire thesis is divided into five sections which are briefly revealed as given.

Chapter 1: Introduction of the optical network and motivation of the project

Chapter 2: Wireless Optical Communication, this provides outline for the optical network, the various terms such as wireless optical system, Wavelength division multiplexing (WDM), and Wavelength routed optical network (WRON), Routing and wavelength assignment (RWA) algorithm are explained.

Chapter 3: Quality of service parameters which gives brief introduction about blocking probability and Mathematical model for blocking probability.

Chapter 4: Designing of Network and simulation, which gives the topology of the network used for purpose of simulation and results of simulations are presented.

Chapter 5: Conclusion and future work, which gives you the complete conclusion of project work along with its future impending.

2.

Wireless Optical Communications

2.1 Optical Networks

As for a network is an interconnection of collected nodes by links whatever may be the network topology. The route needs “transmission equipment’s” and the nodes needs the “Switching” by using these two equipment in the network the technology improvement is up to date and we say that the optics is awesome to transmit data faster than the other conventional methods, for transmission of data i.e. an optical fiber can amplify all signal simultaneously and all these signal on a multiple wavelength channel on a only one fiber link , whatever may be wavelength available on the particular path without knowing the traffic load for a given network. However, most of the efforts at the emerging of all optical switches have shown the starting point of the optical switching. As we know the optical network is not absolutely optical because of the transmission and reception uses switches and the routers but the transmission is necessarily optical. Here in this technique an optical is not sure that it is a packet switched or circuit switched or the sub wavelength granularity bandwidth pipes, or the collection of packets which is also known as a “bursts”.

Optical Networks of first generation are works simply by optical fibers substitute the copper wires. Despite, there are some dissimilarities among the fiber and copper as communicated media:

Optical system assets are to be upgraded on the grounds that as contrast with electronic devices, the optical devices are more prosperous. The information processing lead into electronic circuits are far less rate than the rate at which optical signals are transmitted. A career with distinctive wavelengths of number of optical signals are in the meantime passed through the same fiber

2.1.1 Optical Networking: Need + Promise = Challenge!

As all we are progressively dependant on the information and society also needs to access the information, which is provided through a global communication network, and the current applications of these are modern Internet and the asynchronous transfer mode networks. Actually we are not able to provide an enough capacity for the conceivable bandwidth requirements so for this we need to update our technology and fiber optic communication is technique which can fulfil all the needs because of the theoretically boundless abilities as given.

1. Low power requirement.
2. Enormous bandwidth. (Up to 50Tbps)
3. Resistance to electromagnetic interference.
4. Low signal attenuation.
5. Low signal distortion, appropriate for transmitting digital information.
6. No interferences and crosstalk among the fibers through the single channel.
7. High security of signal as there is a no electromagnetic radiation.
8. Needs very small amount of power.
9. Extraordinary electrical resistance, beside of high-voltage equipment or the areas with large difference in earth potentials we use optical network.

For getting the information networking demands we have to improve the optical fiber technology for the conceivable future. In the optical communication where the large number of users share data networks and we have to provide them but for that we need the large bandwidth for the demanding networking applications. Such as we are surfing the data on the internet i.e. World Wide Web (WWW), and various audio and video conferencing application, Images and the text sharing etc. there arises severe necessity of very large bandwidth transport network amenities, whose proficiencies are much afar from the network which is providing now. Here we can consider that the single mode fiber potential having a bandwidth of 50Tbps, which is nearly 3-4 times larger than the data rates of the tens of Gbps, every struggle must be built to knock the large opto-electronic bandwidth.

2.1.2 Optical Fiber

A very thin glass cylinders that transmit the light signals as an information are Optical fiber. Generally, the data stored in any device establishes connection using optical fibers to an optical network. These system consist of optical devices to get the optical signals from electrical signals to enable the communication of data. These optical signals retrieve and sends via fibers and pass the signals through optical network.

Fiber having distinct significance that to get the outstanding physical medium for high speed networking. As well the conventional fibers, full spectrum has an outstanding properties that can attract by the various large industries, for the reason of shortened water peak, also the various application in the L-band. Full band uses taken into account that for the WDM having an operating range of 1270 to 1610 nm for a single fiber link. So from this we can conclude that the Full-spectrum fibers supports more functional wavelengths of that the standard single-mode fiber and therefore we are getting large bandwidth for each and every fiber.

Optical fiber consists of two concentric glass layers (shown in figure 1), the inner core and the outer clad with a lower refraction index. A third protective layer, buffer coating, is applied as the materials and protects the optical fiber especially against the moisture and abrasion, which might degrade the fiber.

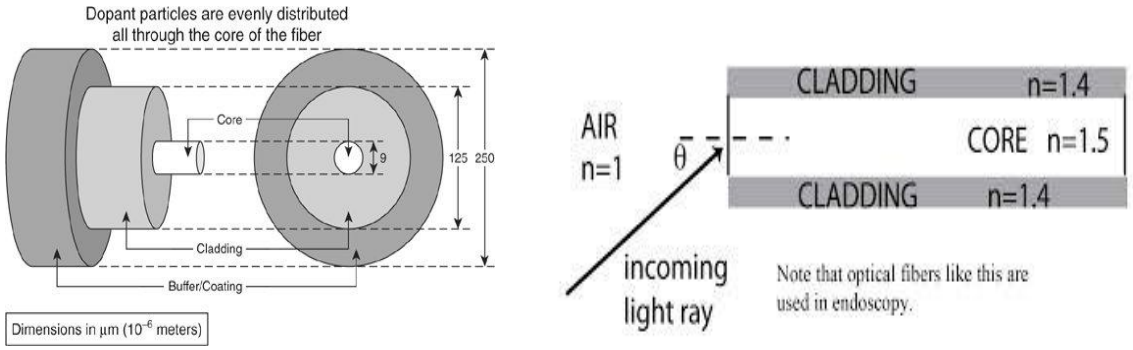

Figure 2.1: Optical Fiber cable.

Optical fibers which have higher bandwidth and are less liable to electromagnetic interferences and depressing effects. Hence these are chosen for data transmission above bit of tens of megabits per second above a kilometer distance. Short distance realizing (a few meters to hundreds of meters), high speed data transmission in large interconnection systems (gigabits per second and above) are chosen in optical fibers. Apparently, it is possible to send data in a single fiber at a rate of 50 tera-bits per second.

2.2 Wireless Optical System

For the future compeers, wireless network facilities might be given by Millimeter wave radio get to in altered access and versatile requisitions. In such system, the degree of recurrence of radio (i.e., RF) signals could be created at a primary station which can bolstered through optical fiber communications to antenna sites. The straight forward radio base stations which are executed could be empowered by the distribution system of optics. We will accordingly examine the adjusted remote correspondence systems with optical fiber as the supplying system for up degree of available remote system, for supporting data rates in the ranges of Gbps which is very wide for these applications. In remote environment multipath delay and fading in signals where single bearer versatile communication backgrounds didn't get the satisfactory results. In such system ISI and blurring in signal happens, multipath impacts because of the recurrence of the channel selection shows up at the beneficial part of the network. Thus, the total performance of the system becomes degrades due to lot of probability of errors. The fixation of errors is done by using the adaptive equalization and channel coding techniques. As that of characteristic delay in the coding and equalization technique and it needs huge cost for hardware, it is not a very easy to use such a techniques in systems operating at very high bit rates, more than Mbps.

Communication model for a wireless optical system is shown in the figure 2.2. Required information or data transmitted where the transmitters are of optical transmitters and then they are modulated for the signal transmission which is fed to wireless medium and then led for the transmission. Detector part consist of the optical receivers which are then converted and the transmitted data is obtained.

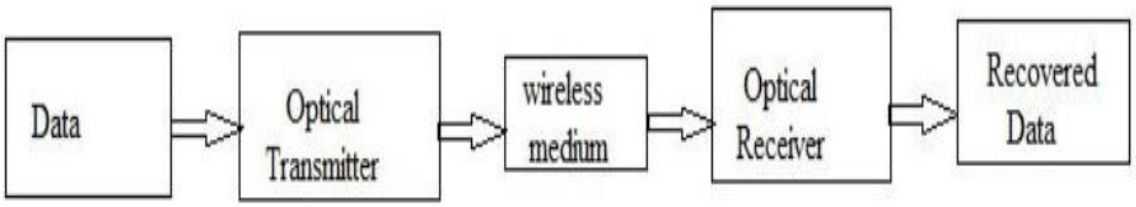

Figure 2. 2: Communication system model of Wireless Optical Link

2.2.1 Optical Fiber Communication System

The basic components of the optical fibre communication system components, are as given transmitter, receiver and the transmission path which is shown in the figure 2.1 [3].

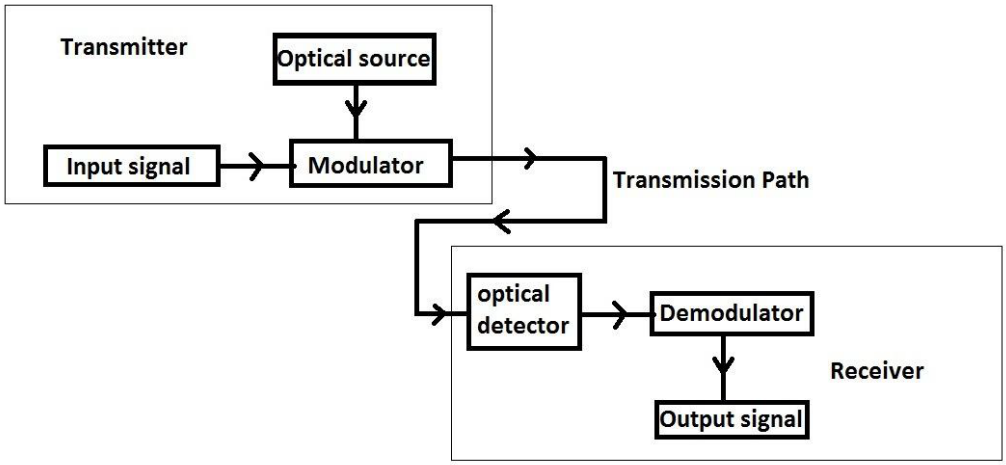

Figure 2.3 Optical fibre communication system

The input signal is provided by the source which is present at input side which is a transmitter, the source is a laser source which provides the light signal which is having a certain wavelength. The source (laser source) and the optical signal are feed to the modulator so that the output is a pulse signal which transmitted through the allowable path which is nothing but a optical fiber. At the other end the optical signal is received by the optical detector, after that the received signal is demodulated to get the input signal which transmitted by the laser source. The optical fibre is a flexible thin filament of made of silica glass receives electrical signals as input and translates them to optical signal. It transmits the optical signal through the fibre length and reconverts the optical signal to original form i.e. electrical signal at the output side.

2.2.1.1. Advantages of optical fiber communication

- Cheap than the traditional wires.
- More flexible and tranquil to install.
- These are less influenced by flame.
- signal can propagate longer transmission distances without the repeater or routers
- They can support the variable speed and bandwidth. Doesn't have speed limitations or bandwidth limitations.
- Effortlessly advancement in the higher speed and high bandwidth.
- It support duplex communications, bidirectional transmission

- They don’t have to struggle through Electromagnetic Interference as they carry light.
- Support large bandwidth of up to 40-100Gbps. as the chances of cross talk are very less and hence the signal loss is very little compared to Copper Cables.

2.3 Wavelength Division Multiplexing

If we are having a only one signal of 10 MHz and the available fiber material having a large bandwidth of 30 THz, so efficiently it is wastage of bandwidth. Hence for the effectively use of bandwidth there are many techniques such as time Division Multiplexing and frequency Division Multiplexing. As the bandwidth of the signal is very large so that's why it is difficult to multiplex the signal in the time domain because it is very tough to generate signal of the femto-seconds range. Now the frequency division multiplexing is the only one which is being evolved as the Wavelength Division Multiplexing. As we know that the optical fibers can transmit multiple light path signals of number of different wavelength simultaneously.

The method which permits the optical fiber to transmit number of signal of different wavelength through the same channel is known as wavelength division multiplexing. Hence the technique of transmitting of several number of wavelengths of light-path at once. By using different wavelengths of light to carry different signals which can be multiplexed by the WDM methodology in fiber optic communication. This helps to improve the capacity and the bi-directional transmission at the transmitting and the receiving end for a single fiber length. Concluding that the WDM probable of transmitting the total throughput in the range of Tbps, so we can say that WDM is the best technique for the increasing demand of the large number of bandwidth.

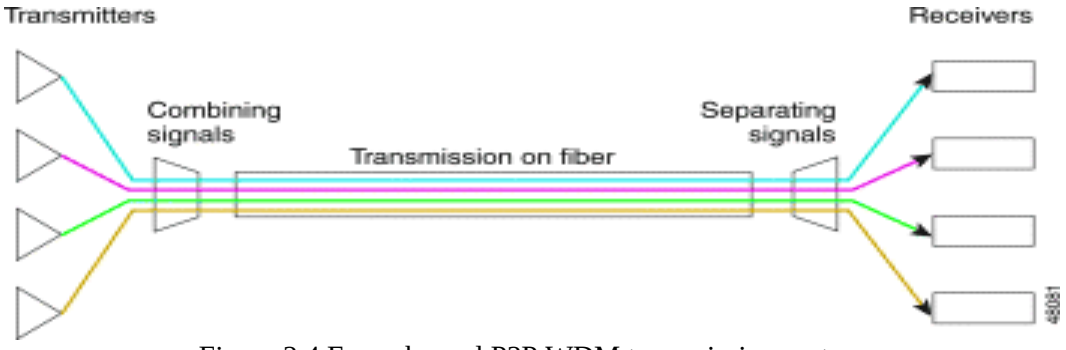

Figure 2.4 Four-channel P2P WDM transmission system

Obviously we all know that the no optical to electrical to optical conversion of data take place immediately after receiving or sending the data in between the routers in the WDM, hence for that we have to decrease the burden on the essential electronics. Optical network has a number of application besides of the point to point communication. The electronics based equipment's present in the network which is not having a very high data rate capacity offered by the optical network because optical network can support a bandwidth in the range of Tbps.

Now a days the new equipped system can manage up to 160 wavelength channels providing a data rate of the 10 Gbps for a single fiber pair to over a 1.6 Tbps. The electronics equipment present at the router controls the traffic along with the handling of data. This increases the burden on the fundamental equipment's significantly. To utilize the all the available bandwidth we require a faster electronic switching device is needed which is having an operating range is in Tbps. But we know that the electronics circuits having their own limitation the voltage and current capability which allow the highest speed of Giga bits. So WDM networks have to use the limited range otherwise there is a optoelectronics miss-match this is all about the first generation of the networks, Now moving toward the second generation, in this technique data are transmitted through nodes, this routed data through nodes is nothing but a router in the optical field There are two types which are opaque and transparent (i.e. all optical). In early stages, Opaque network is used which devours large power and they are not scalable to satisfy future demands this is the another issue with these networks. These disadvantages can be overwhelmed by the use of optical networks, which is highly scalable along with larger data carrying capacity and also consume a small amount power. This is realised since when all optical WDM network removes [1, 3] the transformations among electricity and light. DWDM is the highly advanced and innovative technology provides potential ability to provide huge bandwidth for a single fiber channel [15] in the fiber optic communication. High closely spaced wavelengths used by DWDM technology. So the large number of wavelengths can be multiplexed providing higher capacity. It can amplify the complete wavelength instantaneously without the need of O-E-O conversion and transmit signal of different light speed and carry data simultaneously through the optical fiber this is one of the significant features of DWDM technology.

Now a days all the WDM networks depends on the circuit switching for the interchange of collected traffic among the nodes. In optical technology it is very easy to construct a circuit switched router than a packet-switched router. From source to destination the circuits are used to establish over light paths. We know that only one wavelength can be used by the light-path from source node to destination node within this transmission there is no wavelength-conversion capability present in the router. Besides, a light path can be established over more wavelengths and having wavelength conversion capability in the router. So the link application will be less as we know only a fraction of a wavelength capacity so the remaining wavelength is wasted, To get over the this fault a Time Division Multiplexing this technique used in WDM network. In WDM networks for estimating a blocking probability lot of research work is going on and is depends on two issues which is a wavelength routing and assignment (RWA)

algorithm, and to estimate the blocking probability (with network topology and available wavelengths).

2.3.1 WDM Network Constructions

By connecting system nodes through bidirectional fibers forming a passive star, a local WDM network can be developed as shown in figure 2.5, using a laser i.e. a source input which generate an optical information which is transmitted through the node to passive star network on one of the available wavelength.to drive the router it needs a sufficient amount of power which is collected by the different data sources and then divides into equal parts and supplied to each router present in the network. By the use an optical filter for node's receiver the node is tuned to available wavelength present in the network, so receives the data stream. The following two methods supports the Communication between sources and receivers are as single-hop, and the other is multi-hop. Also, keep in mind that when a source node sends information on a particular available wavelength which is having data available on the wavelength λ1, number of receiver can be tuned for accessing the data from to wavelength λ1, from the tuned receiver which can access the wavelength λ1 draws the information following network support "multicast" services.

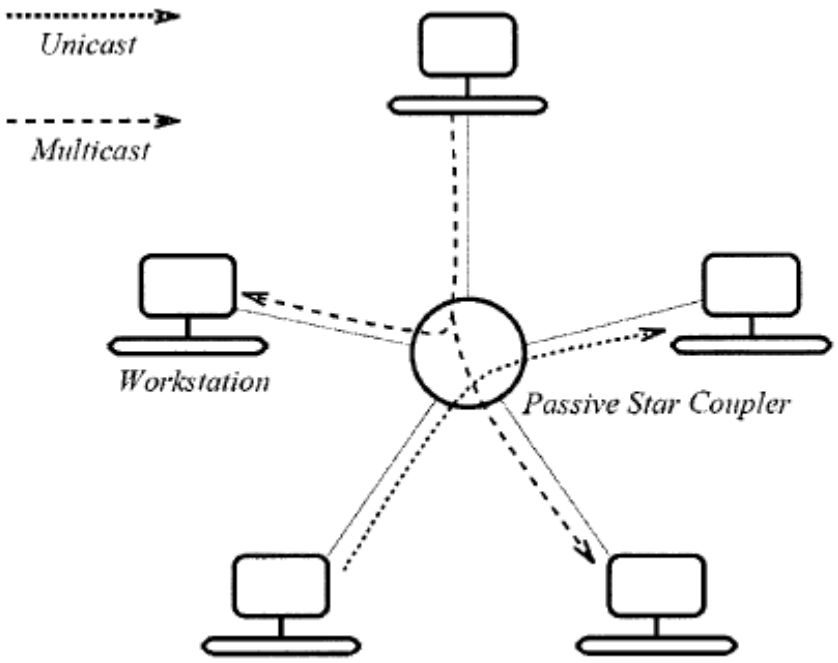

Figure 2.5 A star-based optical WDM network.

2.4 Wavelength-routed optical WDM network with light-path connections:

In WDM networks, the interchange information with each other with the end users over all available optical WDM channels, is known as light-paths. Which is a provisions of connection in WDM network may be of number of fiber links as shown in Fig.2.6

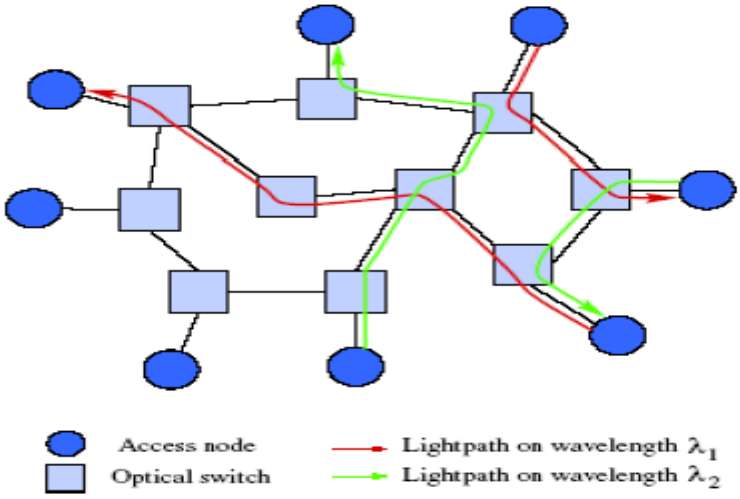

Figure 2.6 wavelength-routed optical WDM network.

For all the optical system a light-path can inhabit the only one wavelength for all fiber links present in the networks. Figure shows that the light-paths is fixed among the pairs of the access nodes for the distinct wavelength this technique is used in wavelength routed optical network. For a setting a light-path with an available set of connections, this assigning and setting a light-path by routing we have to know about the routing and the allocation of the wavelengths which is also known as a RWA algorithm

As we know the for inadequate number of wavelengths in fibers, for the transmission of data RWA is the challenging network issue for that routing in WDM networks the available connection request should be static, partial static or the completely dynamic. For a fixed traffic we know all the connection request and we have to fix all the light-path. The Static light-path establishment (SLE) is a technique for reducing the network resources for the RWA issue in the static traffic. For partial static that is incremental traffic, the path request arrive in sequence and the light-path produced for the each connection and rests as it is in the network. Beside for dynamic traffic a light-path is recognised for the available connection request arrive, the main

motto of these two technique i.e. incremental and dynamic traffic case is to provide an light-path and assigning the wavelength so we can reduce the connection blocking so we can maximise the number of connection which are established in the network by this the network throughput can be increased up to a good extent.

2.5 Routing and Wavelength Assignment

RWA is an algorithm for the providing the connection among the SD pair and assigning wavelength for the established path. Since in WDM network only one fiber can nearly accommodate upto 120 wavelength no doubt with the technology advancement the increase in the number of wavelength. The main function of the RWA is the gain the best possible performance for the network within the physical limits of the parameter. It is called as NP complete, so it is given by only two steps which is nothing but using a routing technique a for an established connection for a SD pair and the other is assigning a free wavelength for the established connection using the wavelength assignment (WA) algorithm.

The technique Dynamic Light-path Establishment (DLE) is used for the RWA issue of dynamic traffic. Which can be classified into two groups such as Routing and Wavelength Assignment. Number of algorithm are exist as shown in the figure below

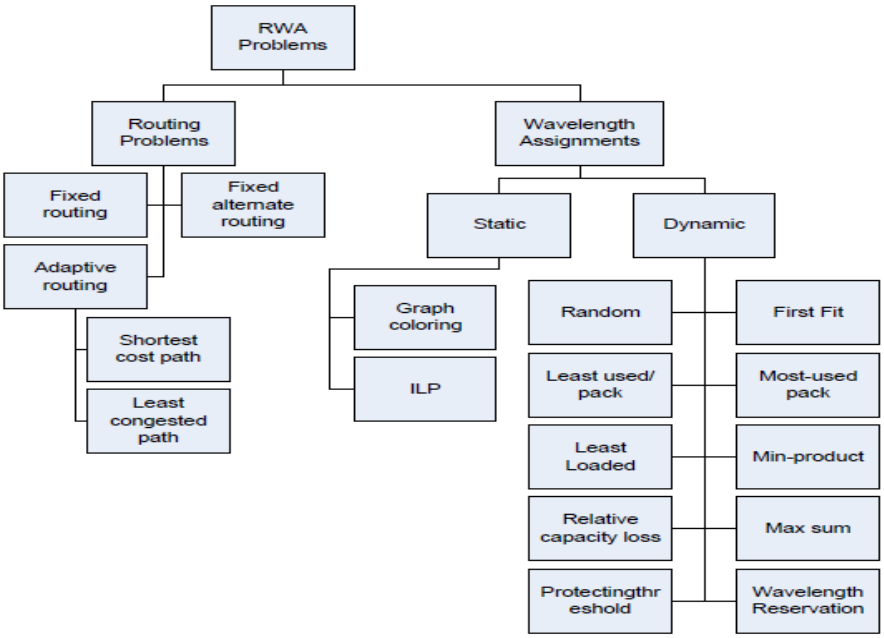

Figure 2.7 RWA algorithm techniques

2.5.1. Routing Technique

In this section some of the important routing/light-path selection techniques are discussed.

2.5.1.1 Fixed Routing (FR)

In this technique a single light-path for a SD pair is estimated, this is a very simple technique as we know the very less number of light-path connection can be available in the given network. As the connection request are available less in number the higher is the blocking probability.

2.5.1.2 Fixed Alternate Routing (FAR)

In the FAR the paths are arranged in the priority, as the several another paths are computed for a SD pair. In this method the shortest path has a highest priority while the rest as depends on their length along with the shortest path a number of links available is also an another priority. When the request for a particular path is arrive then, source is searching for the available connection and then the destination until the search going on for a free wavelength if if link is not available then arrived request is blocked. In this method the blocking probability can be reduced, so we can say that the FAR is better than the FR technique.

2.5.1.3 Adaptive Routing (AR)

The computation of the connection is totally a depends on the network state and the sources available at the present time when the request is arrived means this is an online technique, the SD pair provides a path which can be adapted dynamically totally lying on state of the network and shortest path is also taken into consideration. As the request is arrived, the shortest path for a SD pair is calculated and when the number of routes are more than one then a random path can be selected otherwise the connection is blocked when there is no request. This is the best technique and is most efficient for the WDM network.

In this thesis, we followed the idea of AR technique.

2.5.2 Wavelength assignment

We know that the wavelength assignment strategies mostly relies on the two strategies that is First fit and the Random fit, the first fit is depends on the lowest minimum index of applicable wavelength and the random fit is decides the assignment depends on the availability of the wavelengths and then chooses randomly between them.

To acknowledge the signal conditioning their an extension to these technique can be used which is nothing but the quality fist fit and quality random fit and they can remove the connection which are of undesirable signal quality, As with the advancement of the algorithm the complexity will be increase.

The number of other methods are available in for the assignment of wavelengths which are as least and most used, Min product, least load, Max sum and relative capacity loss. These techniques are rarely used but are effective, apart from these most used technique is better than the least used use knowingly which is slightly more effective than the first fit. Remaining methods all are attempt to choose a wavelength which is available so that they can blocked the future request and minimize the probability. The centralised network structure makes this technique ideal for a significant communication this is the main disadvantage of the these algorithm.

2.5.2.1 WAVELENGTH ASSIGNMENT ALGORITHMS:

A. First fit (FF):

First Fit strategy all the time chooses the lowest indexed wavelengths, so the available wavelengths of traffic load matrix are arranged in the increasing order from this list of available wavelengths and assign it to the suitable connection request as soon as the request for the connection is done wavelength is available in the free set of wavelengths.

B. Random fit (RF):

Set of free wavelengths on particular path is determined. RF algorithm checks from the available wavelengths and then it selects casually from the available set of free wavelengths. The random selection of wavelengths is pretty much easy that the first fit.

C. Most used (MU) and least used (LU):

Whenever the connection request is made it get to be allocated by the wavelength which is using depends on the maximum number of fibers present in the network. The other is technique least used (LU) wavelength assignment is almost similar to the most used algorithm except in LU algorithm the least used wavelength in the wavelength is allocated. Least Loaded wavelength assignment selects the least loaded wavelength on a most loaded link. This wavelength available on maximum number of fiber for transmission.

3.

Quality of Service Parameters And Mathematical Model

3.1 Quality of service parameters

The importance of network congestion management and Quality of Service makes the network developer to perceive the data loss, delay and its sensitivity has increased in these days. To reduce the delay, delay jitter and losses in packet became the major charge to build the buffer management tools for the network builders. It is requires to understand the traffic for building the network management tools. To sustain the capacity of the network maximum, QoS has to be complied with service provider of the network is possible only when the traffic modelling is made accurate by enhancing traffic resources. To provide the altitudinous discriminating QoS for the network and its traffic network model will have their impact on it.

Applications of real time have severe necessities for delay jitter, loss and delay. Quality of data near receiver is worse because of the delay in packet and loss in packets. In data transmission there will adverse gaps and interruption in data due losses in data packets. In real time applications, the data which is just arrived will overrides the previous data, where the loss of packet is comparably same as the packet large delay. The information regained at the receiver is in need of repair by the large jitter delay. Delay propagation and link error are some of the sources for the delay and loss of packets. In this we have concentrated only on the delay in data because of queuing in router and exceeding of buffer. The interface among the network and traffic will be affected by the delay and loss in data for example congestion. Parameters of QoS is explained.

The various factors affected by the quality of service in a packet switched networks are divided into two factors such human (humanoid) and the technical factors, the humanoid factors are as service stability, delay, availability of service, user information and the technical factors include the effectiveness, consistency, maintainability, grade of service and scalability. As we are using the packet switching lot of things occurs to the packets as these packets are transmitted from source node to destination node facing lot problems from the transmitter and the receiver point of view.

3.1.1 Low throughput

As we know that the varying load provided by the large users available in the same network, the various parameters are getting affected such as the bit rate which is provided for a certain information stream which is too low for the real time multimedia services and if all the information stream having the same scheduling priority.

Loss rate is nothing but the fraction of the total number of packets dropped to the number of packets input bounded by the period of time.

$$Loss\ rate = \frac{Total\ number\ of\ dropped\ packets}{Total\ number\ of\ input\ packets} \tag{3.1}$$

3.1.2 Latency

For a packet to reach from source to the destination it will take a sometime, because it stuck in a long queues, for avoiding congestion it took a less direct route, which is from the throughput, for a long time the delay can never built up, whatever may be the fact but the throughput is always having a standard value. In any case, at times enormous latency provides uses such as VoIP or the online gaming. Due to transmission of packets in router and staying in a queue for a packet in the obstacle of the service. For service and queuing delay.

3.1.3 Jitter

As we know to reach a packets from source to destination with different delay. The packet delay is distinct from the starting means its place in the queue of the router besides the connection from source to the destination and this can be changes eccentrically. This discrepancy of a delay recognized as jitter and dangerously affect the quality of streaming audio and video too.

3.2 Blocking Probability

For a new connection request we need an RWA algorithm to set up a connection between SD pair and as there is no link available from source node to destination nodes for the available wavelength the connection request is blocked.

Among the quality of service parameters blocking probability is crucial parameter which is used to compute the performance of a given WRON for a different kinds of circumstances. Actually it is not easy to compute precise theoretical BP in the optical system, since we don't know the exact traffic load on a typical link, along with the other factors such as the network topology and the number of wavelengths. Other technique which is having a more influential tool which is discrete event simulation to achieve the blocking probability for evaluating the impact of the network parameters which is not easy to model.

This model brings the point of giving the relatively different blocking probability for different paths and the various scenarios for the different topologies of the WDM network. At the wavelength level a focused blocking computation is executed.

3.3 Mathematical model

The traffic load distribution is the main parameter while estimating the BP and this is relies on the others constraints which are network topology and RWA technique, here we consider a WRON with an Arpanet topology is taken into consideration along with this a shortest path algorithm is taken into account to pick a route among the SD node pair . So the given number of edge nodes available in the topology which is calculated by the following equation 3.2. [13,14]

$$R = Ed \times (Ed-1) \tag{3.2}$$

Number of SP routes for each SD pair is denoted by 'R'. So all these routes uses a minimum number to get connected with available links present in the network which can connects two nodes and to compare the shortest path the two different algorithm is used which are minimum hop (MinHop) and minimum distance (MinDist). MinHop depends on the number of hop as route the cost while the other technique uses the distance between the two nodes as the link cost expressed in km which is nothing but a MinDist algorithm

Therefore by computing all available possible routes for SD pair present in network, the fixed distribution of available routes in the network can be represented by a n×n matrix R(s,d), the network having n nodes i.e. the number of network nodes and each nonzero element R(i,j) is the number of available routes supported by each link between nodes i and j presented in the network, by applying the network load ρ_{net} to a given network , the load matrix can be computed by the following equation

$$T = \frac{\rho net}{\sum_{i=1}^{n}\sum_{j=1}^{n} R(i,j)} \times R(S,D) \tag{3.3}$$

Where, R(S,D) is the possible route for a SD pair and

R(i,j) all possible route for link between node i and i

T is a n×n matrix, where n is the number of network nodes and each nonzero element

For the network resources that are shown by the wavelength matrix, and the number of wavelength 'W' on each link between node is given by W(i,j) so the blocking probability using an Erlang-B formula can be calculated for each link which is shown in the below equation. [13,14]

$$BP(i,j) = \frac{T(i,j)^{W(i,j)}/W(i,j)!}{\sum_{s=0}^{A(i,j)} T(i,j)^s/s!} \quad (3.4)$$

Now we are calculating the BP of the total network 'B_{net}', the BP matrix contains BP for a each link taken into account for each link is submitted to T so by using the following equation,

$$Bnet = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} BP(i,j).T(i,j)}{\sum_{i=1}^{n}\sum_{j=1}^{n} T(i,j)} \quad (3.5)$$

We are now calculating the total network probability where the all the parameter which T(i,j) is dependent on the blocking probabilities link among the nodes i and j . Thus the prediction for the network into an independent links and the available traffic on each link can lead to an inaccuracy in the calculation of the optical network BP.

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Therefore, another estimation strategy is proposed with a specific end to assess a superior estimate BP, which will utilize the estimate for the theoretical BP on each nodes i.e. B_{node}(i) can be expressed as.

$$\text{Bnode(i)} = \frac{\sum_{j=1}^{n} \text{B(i,j).T(i,j)}}{\sum_{j=1}^{n} \text{T(i,j)}} \quad (3.6)$$

4.

Network Design And Simulation

4.1 Network Design

Generalized communication optical link model is shown in figure 4.1, here the signal is transmitted by the optical transmitter i.e. transmitting device which contains data or information in the form of wavelengths over the wireless channel. We consider the routers are established in a range of area of meters distance from routers to routers where the data transmission is carried via routers. Figure shows the design of a network which is interconnected via wireless logical link from source to destination via router and different type of media.

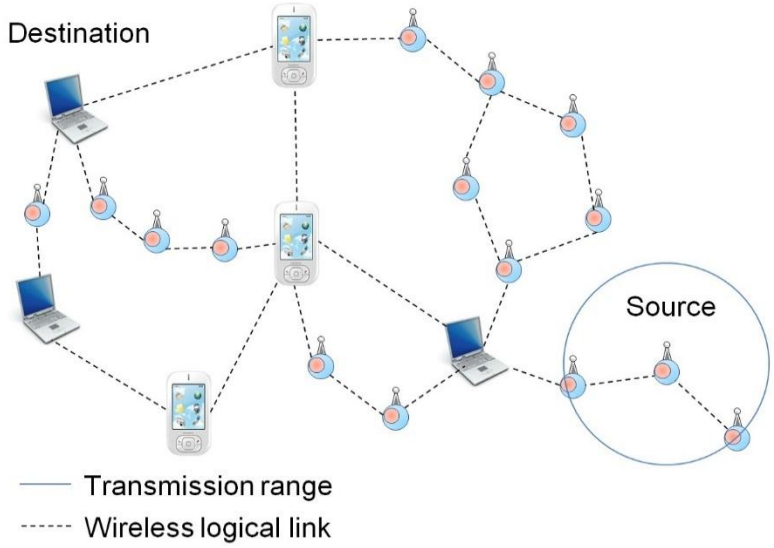


Figure 4.1. Generalized optical link model

4.2 Network Topology

The access points (AP) is nothing but a routers in the network topology, two adjacent routers establish a logical link both are having a same distinct operating wavelength on the same channel. A network topology is consist of the sets of nodes and logical links. Fig.4.2 shows a logical topology 10 nodes and 16 links in the network which are at random distance. Here we considered the nodes as nothing but the optical wireless routers where the transmission of data is carried. The data transmitted over the signal. We considered the signal in the wavelength form. Number of wavelengths are selected which are of 2, 3, 8 and 16. We fixed the source as any node and destination remaining node excluding the source node for data transmission and QoS of the transmission are calculated by simulation.

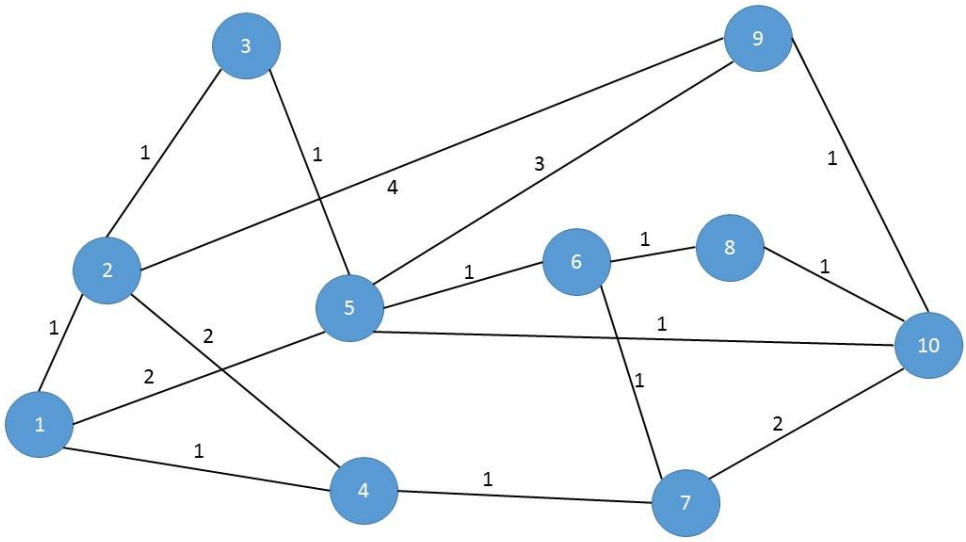


Figure 4.2: NSFNet Topology, Weight represents the number of spans, 1 span=70km

4.3 Simulation for QoS parameters

4.3.1 Computation of All Possible paths

The computation of all possible path is done by the conventional method i.e. depth first search (DFS) algorithm. The DFS algorithm consider the multiple constraint but here we are calculating the all possible path considering only one constraint which is path length.

4.3.2 Computation of disjoint paths:

In a graph, two paths with common end points that have no other points in common. The disjoint path gives the minimum number of paths that can be use at one time in a network, the following algorithm shows disjoint path computation.

4.3.3 Computation of Shortest paths:

The shortest path between two vertices is a path with the shortest length (least number of edges). Call this the link-distance. We can calculate the shortest path using different algorithm example Dijkstra algorithm but here we use a simple technique from disjoint path which link having the least weight can be taken as shortest path

4.3.4 Blocking probability

As we have already discussed the different parameters of QoS in chapter 3 in which blocking probability is the major factor for service requirement. For that purpose we have considered blocking probability as the major problem and simulation is done for it. The shortest path for the above network topology of all possible paths are calculated for fixed source and destination. Using the algorithm we have find path and for that path the blocking probability for different wavelengths has been simulated. For simulating the blocking probability. The following algorithm for intended to estimate the BP of the given network.

4.3.4.1 Algorithm proposed:

The proposed algorithm for estimating the blocking probability is explained in algorithm given below the various parameter i.e. the number of available paths for each SD pair is shown by T matrix, number of nodes ‘n’ in the network topology and the available wavelength ‘W’ for each possible route in algorithm the load matrix ‘P’ can be calculated by the parameter shown in algorithm from that the total network blocking probability and the node blocking probability is calculated shown in the algorithm.

```
Get T, A, n
 P=ρnet*(T./sum(sum(T)))
 %% Wavelength is 8
  z=zeros(10,10);
for i1=1:n
    for j1=1:n
        for s=1:(A(i1,j1)+1)
            z(i1,j1)=z(i1,j1)+((P(i1,j1).^(s-1))/factorial(s-1));
        end
    end
end
for i=1:n
    for j=1:n
        B(i,j)=((P(i,j).^A(i,j))/factorial(A(i,j)))/z(i,j);
    end
end
for i=1:n
   Bnode(i)=(sum(B(i).*T(i)))/(sum(T(i)));
End
```

4.3.4.2 Flow Chart

Figure shows the flowchart for the mechanism to calculate the blocking probability along which uses an algorithm to get the different value which are wavelength and the nodes if these values are not available then the algorithm can't go further it will remain within the loop until he gets these parameters.

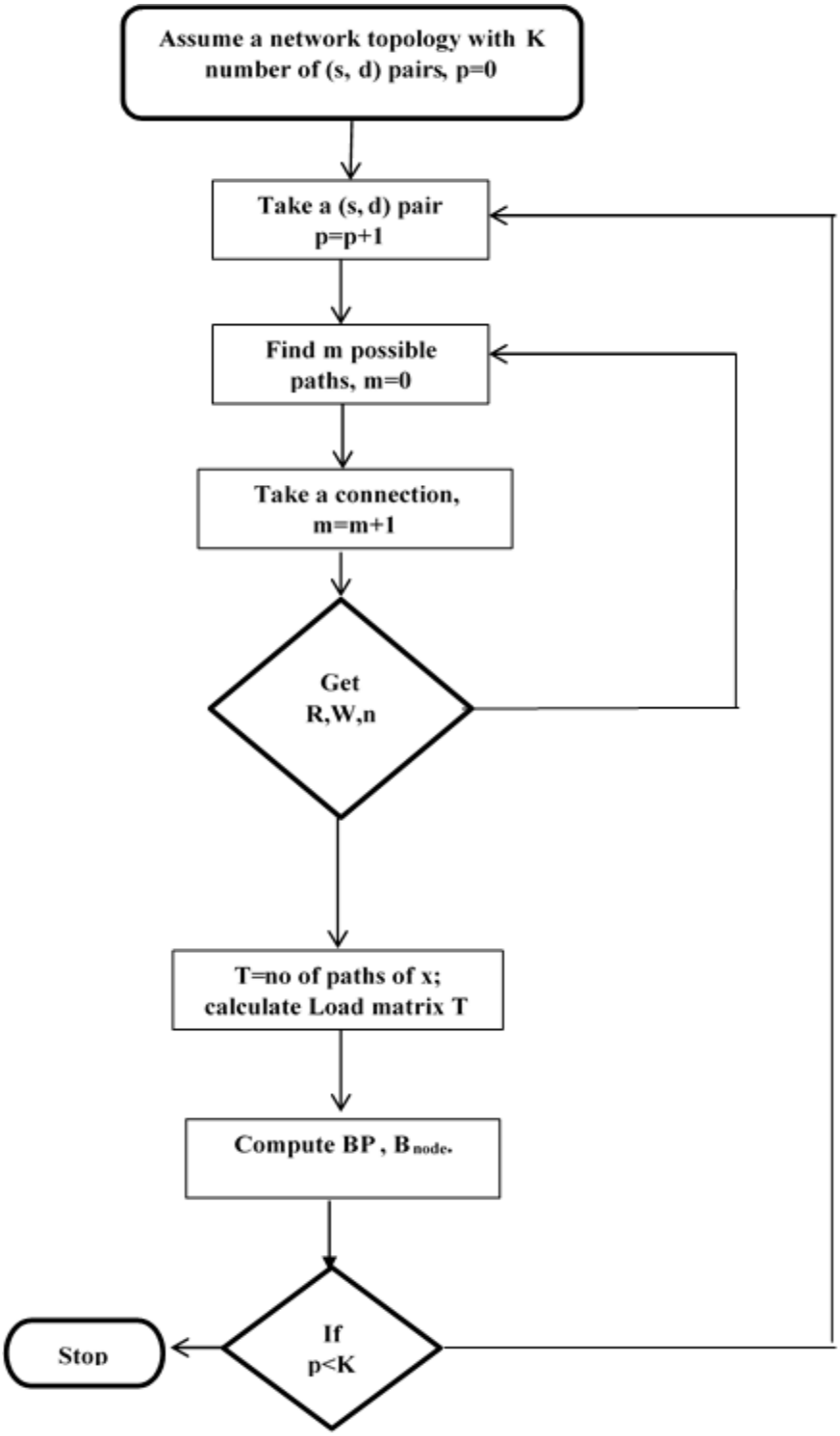


Figure 4.3 Flow chart for BP calculation

4.4 Simulation Results and Discussion

The proposed QoS estimation technique is validated by simulation studies. An AON of 10 nodes and 16 links is considered as per NSFNet topology. This is a widely used benchmark network topology [3, 55, 56].

For simulation some assumption are as given.

• Same types nodes presented in the network topology.

• Number of wavelengths for transmission is same throughout the network.

Table 4.1: Parameters Used for Simulation

Parameter	Values
Maximum number of wavelength	1,2,3,8,16
One fiber span	70 Km
Network load	50E, 100E, 150E

Simulation Parameters are shown in Table 4.1. Considering that the topology nodes are edge nodes, MinDist algorithm is used to compute the SP for each of the SD link which is available for the adopted topology is shown in Fig.4.2

4.4.1 Effect of network Traffic load with number of wavelengths for all possible paths

For the analytic simulation we have assumed the NSFnet topology shown in figure 4.2. The maximum number of available routes (path) for each SD pair shown in Figure 4.3. Suppose we are looking for a SD pair it is having a 26 path available out of 260 available routes at node 2 means that the total arrived traffic for different destination.

For different scenarios the influence of the various parameters such as traffic load, network topology, distribution of network resources, and routing algorithm is calculated by using the given algorithm.

The following figure shows the all possible routes from each node to remaining nodes as for for the same node the available path is always zero. From node 1 (source node) to node 2 (destination node) there are total 26 paths are available as shown in figure. The total number of available paths for source to destination is shown in figure.

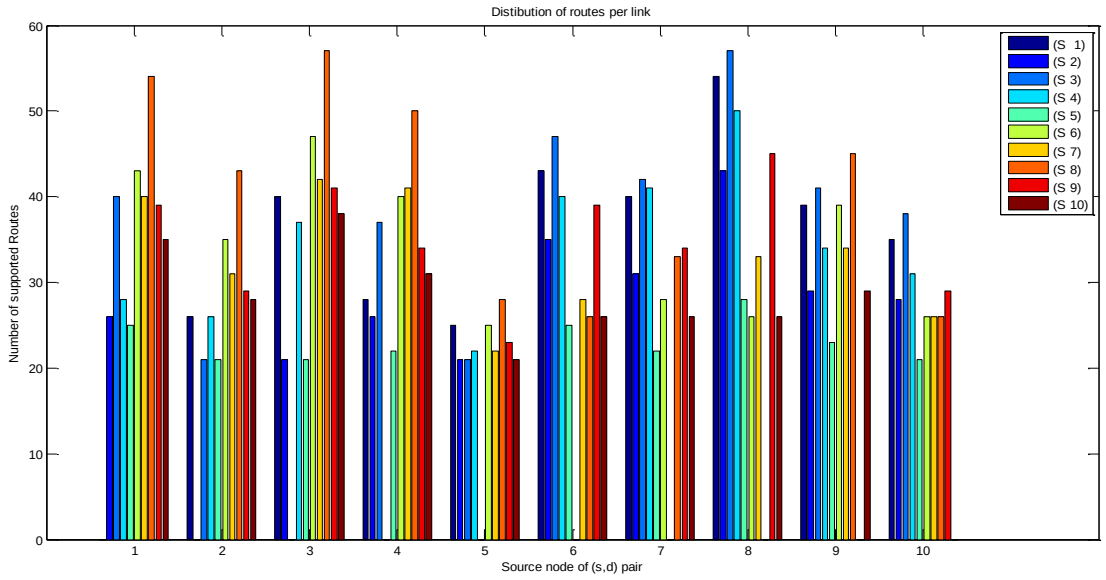


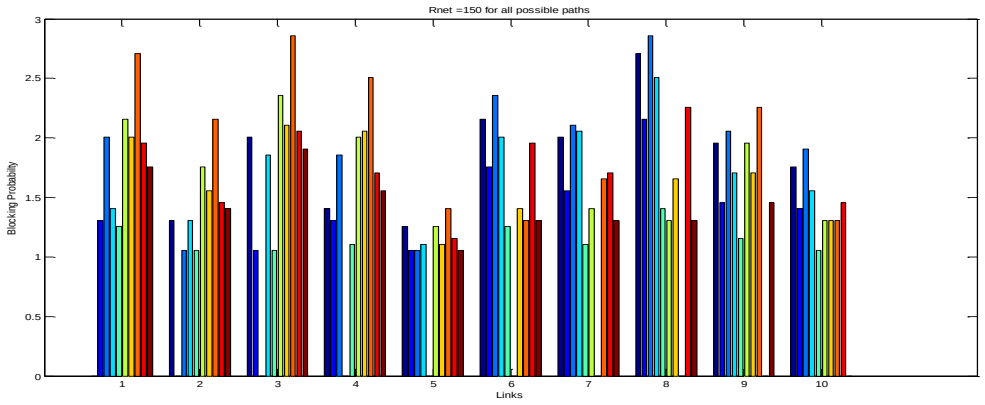
Figure 4.3 Distribution of routes per link

The following table shows the number of available paths

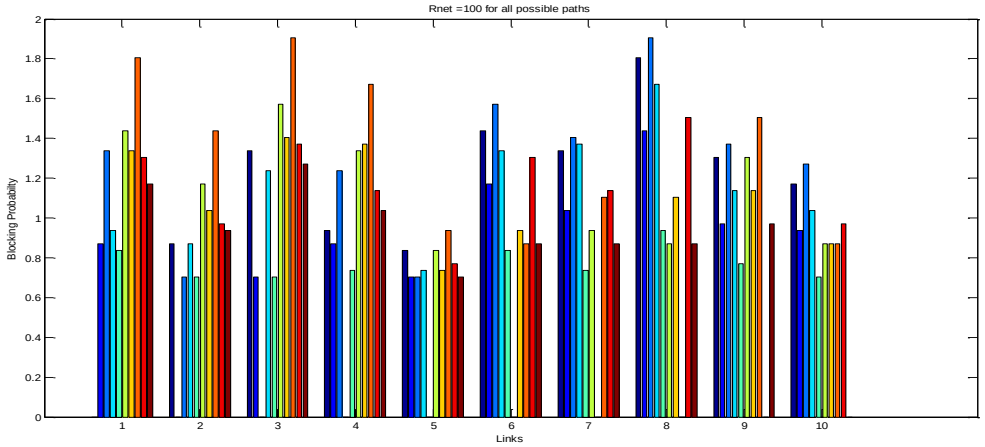
Table 4.2: All possible path available for a SD pair (1,2)

SD pair	Possible path	Possible path number
(1,2)	1 2 0 0 0 0 0 0 0 0	1
	1 4 2 0 0 0 0 0 0 0	2
	1 5 3 2 0 0 0 0 0 0	3
	1 5 6 7 4 2 0 0 0 0	4
	1 4 7 6 5 3 2 0 0 0	5
	1 5 9 2 0 0 0 0 0 0	6
	1 5 10 9 2 0 0 0 0 0	7
	1 4 7 10 9 2 0 0 0 0	8
	1 5 10 7 4 2 0 0 0 0	9
	1 4 7 10 5 3 2 0 0 0	10
	1 5 6 7 10 9 2 0 0 0	11
	1 5 6 8 10 9 2 0 0 0	12
	1 4 7 6 5 9 2 0 0 0	13
	1 5 9 10 7 4 2 0 0 0	14
	1 4 7 6 8 10 9 2 0 0	15
	1 4 7 10 9 5 3 2 0 0	16
	1 5 6 8 10 7 4 2 0 0	17
	1 4 7 10 8 6 5 3 2 0	18
	1 4 7 6 5 10 9 2 0 0	19
	1 5 10 8 6 7 4 2 0 0	20
	1 4 7 6 8 10 5 3 2 0	21
	1 5 9 10 8 6 7 4 2 0	22
	1 4 7 6 8 10 9 5 3 2	23
	1 4 7 10 5 9 2 0 0 0	24
	1 4 7 10 8 6 5 9 2 0	25
	1 4 7 6 8 10 5 9 2 0	26

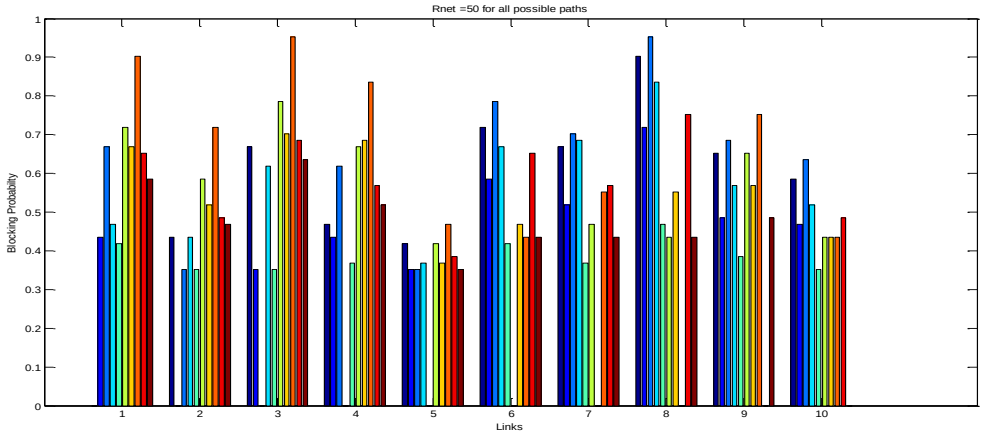
For each link we are calculating the load matrix for different traffic intensity which is given by equation 3.2 for different load i.e. 150E, 100E and 50E we are calculating the load matrix. We are getting the different values for each traffic load as shown below in the figure 4.4 a, b and c.



a) Network load =150E



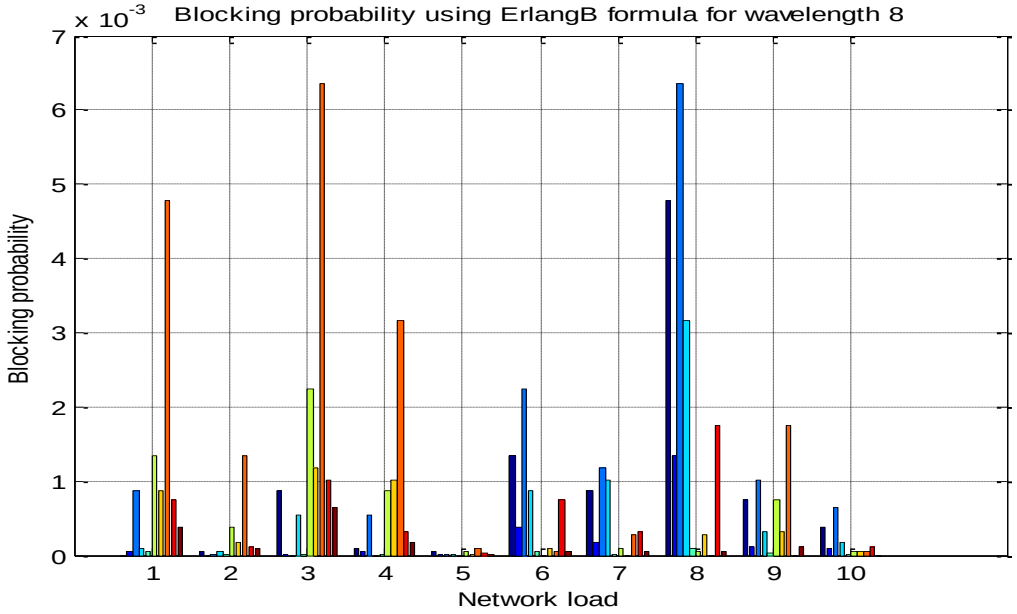
b) Network load =100E



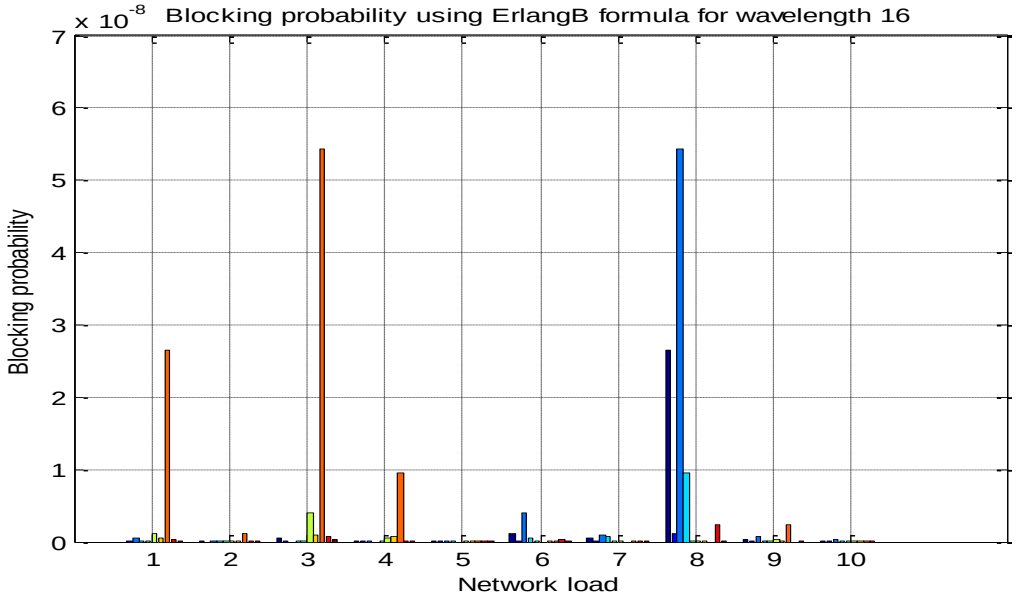
c) Network load =50E

Figure 4.4 load matrix for different network load a) 150E b) 100E c) 50E

The blocking probability for each link for the traffic load of 150E and for wavelength 8 and 16 is as given in figure below using the Erlang B formula.



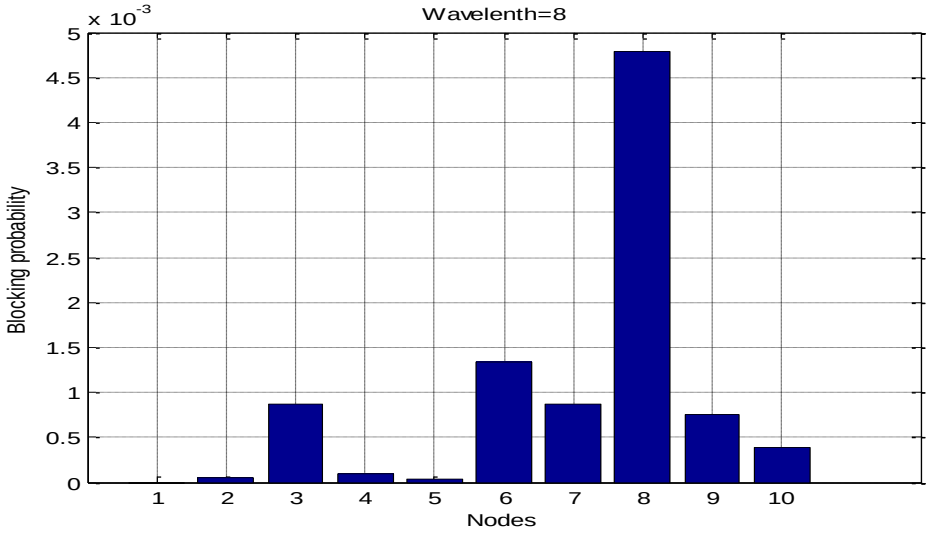
a) Wavelength λ=8



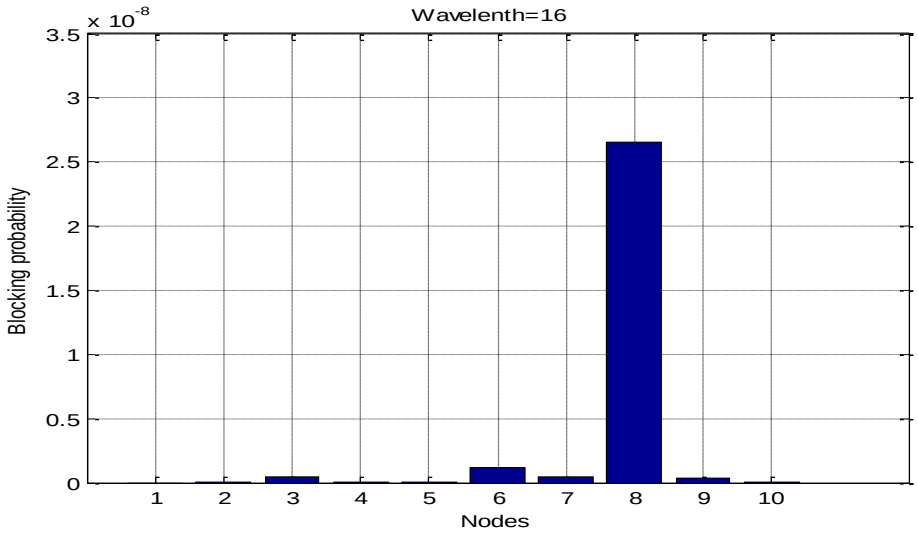
b) Wavelength λ=16

Figure 4.5: Blocking probability for each link and different wavelength a) λ=8 b) λ=16

The figure shows the blocking probability B_{node} for each node can be calculated using equation 3.5 can be calculated which is shown in the figure below for different wavelength. (i.e. λ=8 and λ=16).



a) Wavelength λ=8



b) Wavelength λ=16

Figure 4.6: Blocking probability for each node for different wavelength a) λ=8 b) λ=16

We can compare these two graphs as given below Figure 4.6 represents the results for the node blocking probability with 8 wavelengths (λ=8) and with different values of network loads ρ_{net}. In this result, node 8 represents a maximum BP of 4.8×10^{-3} for the network load ρ_{net} =150E. It supports 57 of the possible routes having maximum blocking probability. Similarly node 8 represents a maximum blocking probability of 4.6×10^{-4} for the network load ρ_{net} =100E It

supports 57 of the possible routes having maximum BP. From this it can say that, if decrease the network load the blocking probability will also decrease.

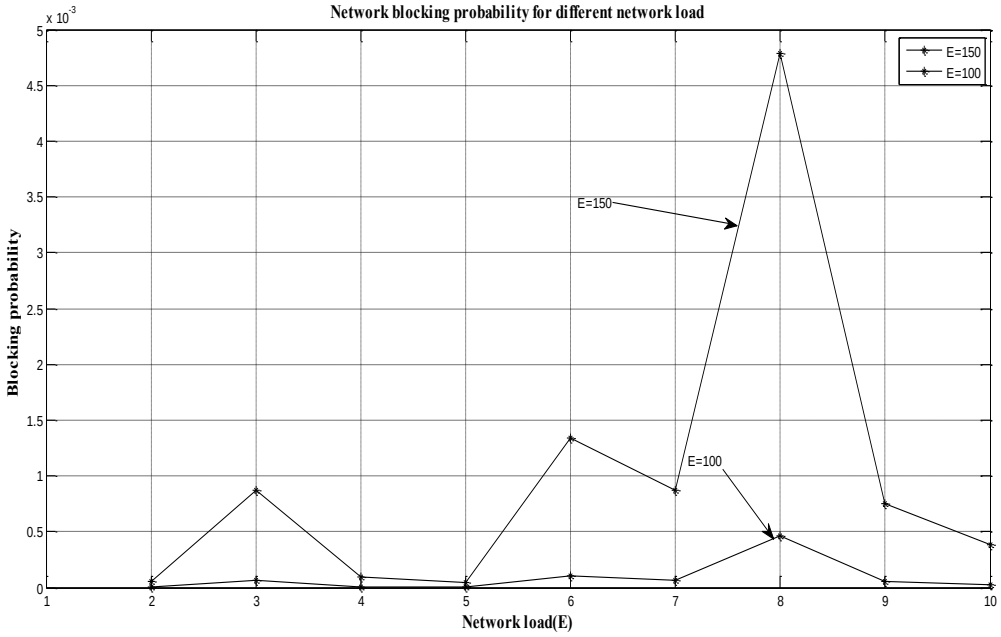


Figure 4.7. Node blocking probability with 8 wavelengths for all possible paths having different network loads ρ_{net} of 150E and 100E

By using the given algorithm for all possible paths we calculate the blocking probability figure 4.8 shows the connection BP verses network load offered by the given the network for the network with 10 nodes, and each fiber link is provided with 8 and 16 wavelengths respectively. As shown in Fig. 4.8 for example, at a load of 180E, 10^{-3} and 10^{-7} getting blocking probability values**.** The information obtained from the proposed algorithm about the quality of the connection and the deficiency in the RWA stage, hence the some of the unnecessary physical layer blocking algorithm is a skipped for the signal quality provision. As the network resources are in intelligent control and are castoff additional proficiently in the destruction aware algorithms hence the light path with a good quality of signal is taken into account. Finally the BP calculated by using the given algorithm is compared with the conventional method show a better performance.

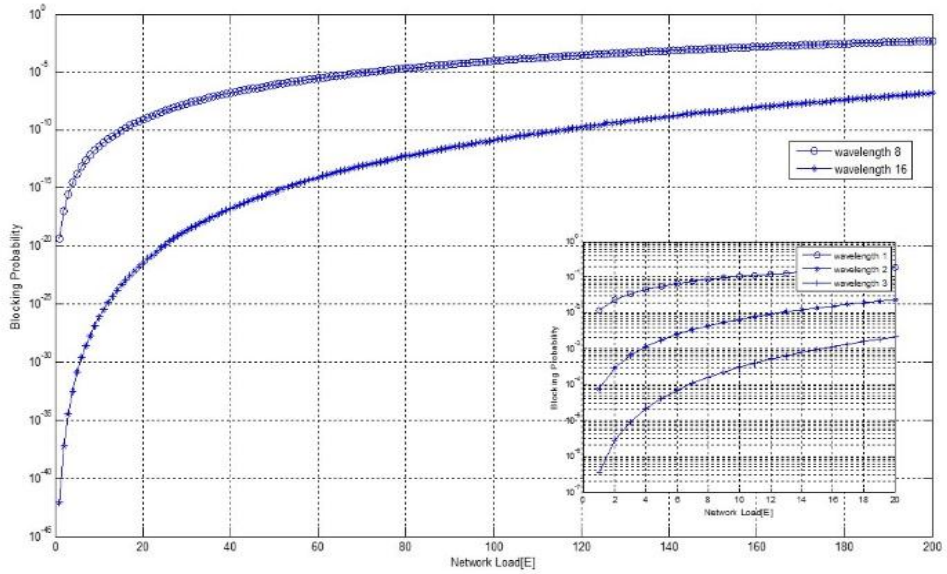


Figure 4.8: Network load Vs blocking probability graph for different wavelength

Fig 4.8 shows different number of wavelengths, the problem with the simulation resolution can be viewed in this figure when using when λ=8 and λ=16,

4.4.2 Effect of network Traffic load with number of wavelengths for Disjoint Path

The following figure shows the disjoint paths from each node to remaining nodes because from node 1 to node 1 the available path is always zero. From node 1 (source node) to node 2 (destination node) there are total 3 paths are available as shown in figure. The total number of available paths for source to destination is shown in figure.

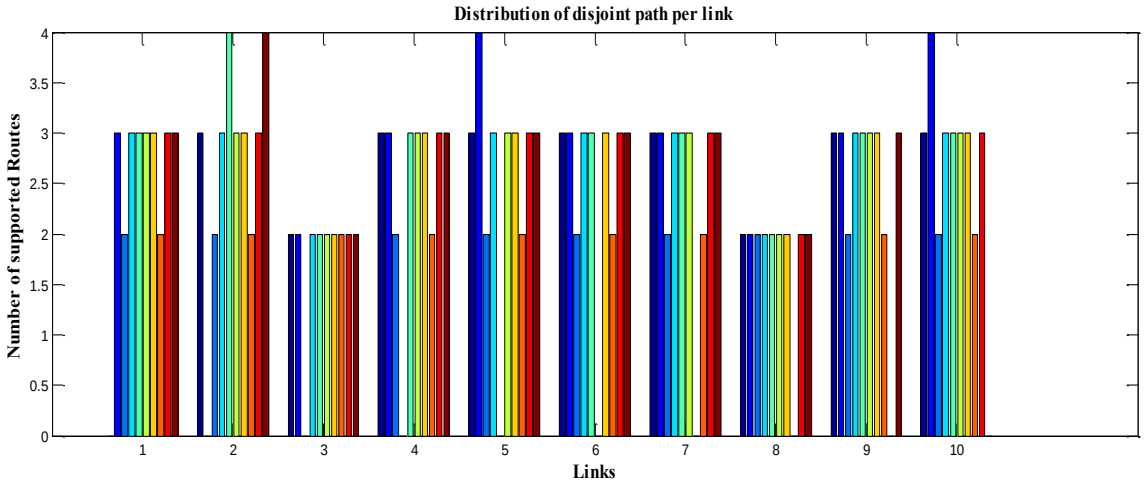


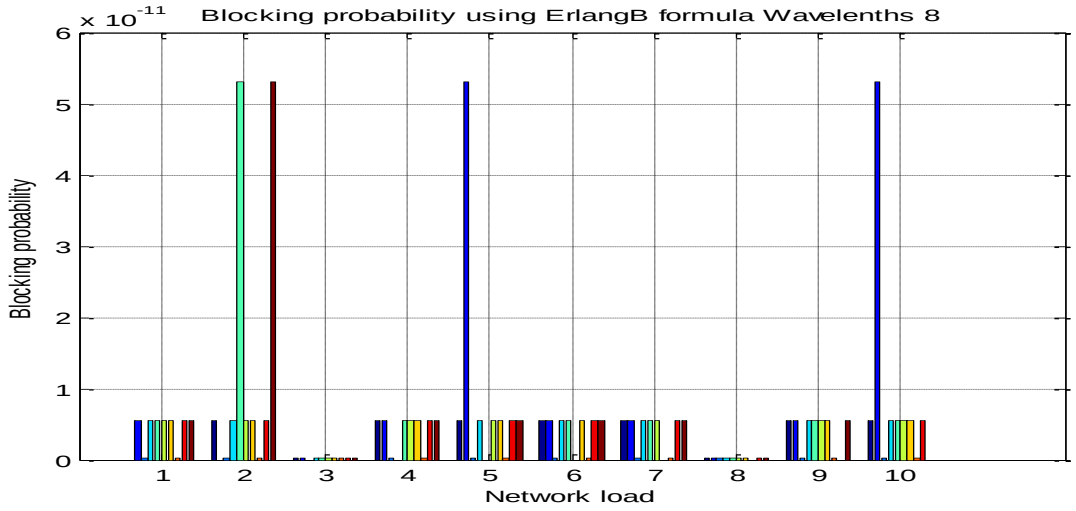
Figure 4.9 Total number of disjoint path for each SD pair

The disjoint OVPNC in a sorted order is given in a table below

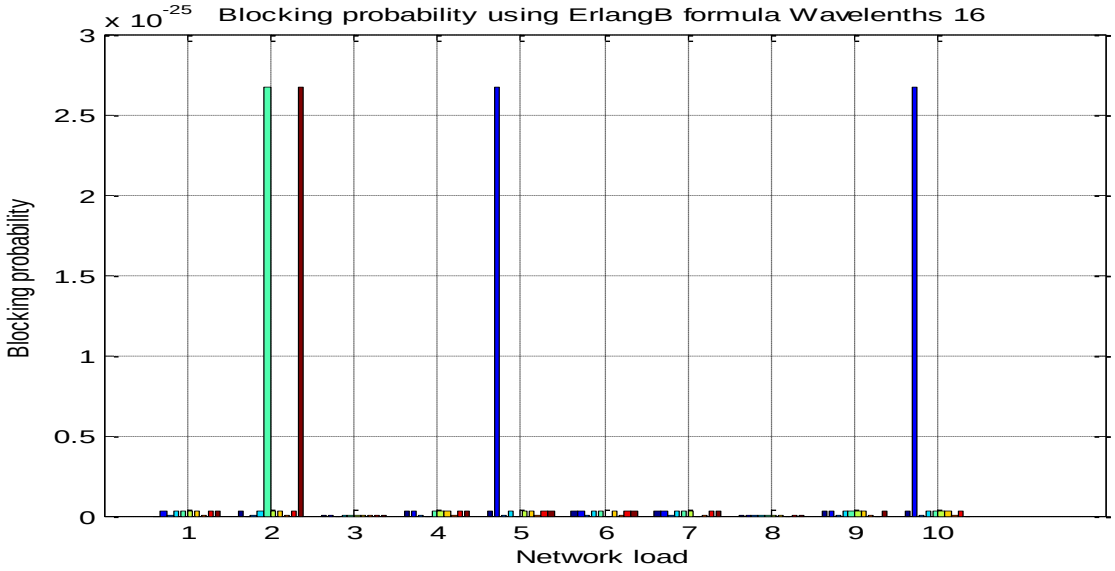
Table 4.3: Disjoint path for a SD pair (1,2)

SD pair	Possible path	Possible path number
(1,2)	1 2 0 0 0 0 0 0 0 0	1
	1 4 2 0 0 0 0 0 0 0	2
	1 5 3 2 0 0 0 0 0 0	3

The blocking probability for each the available disjoint path for the traffic load of 150E and for wavelength 8 and 16 is as given in figure below using the Erlang-B formula.



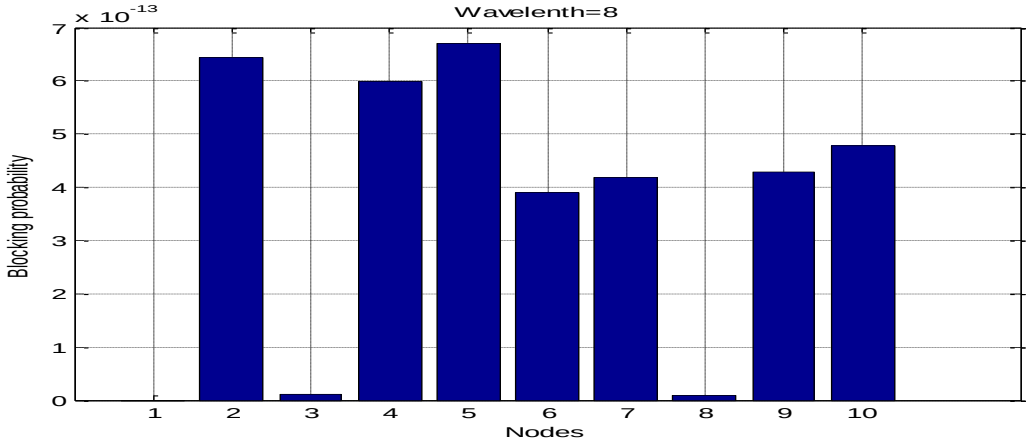
a) Wavelength λ=8



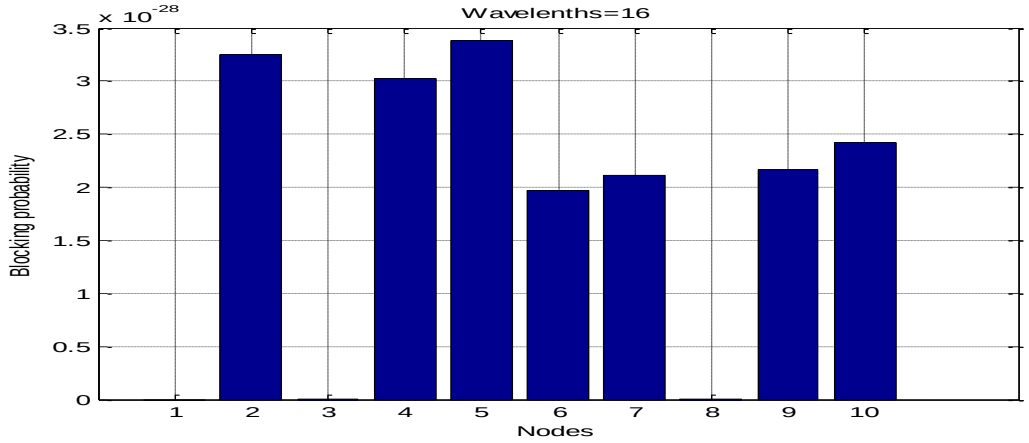
b) Wavelength λ=16

Figure 4.10: Blocking probability of disjoint path for each link and different wavelength a) λ=8 b) λ=16

The figure shows the blocking probability B_{node} for each disjoint path node can be calculated using equation 3.5 can be calculated which is shown in the figure below for different wavelength. (i.e. λ=8 and λ=16).



a) Wavelength λ=8



a) Wavelength λ=8

Figure 4.11: Blocking probability of disjoint path for each node for different wavelength a) λ=8 b) λ=16

Figure 4.11 a) represents the results for the node BP for disjoint path with 8 wavelengths (λ=8) and with two values of network loads ρ_{net}. In this result, node 8 represents a minimum BP of 0.2×10^{-13} for the network load ρ_{net} =150E. It supports 2 of the possible routes having maximum BP. Resulting an average of Request will arrive at this node.

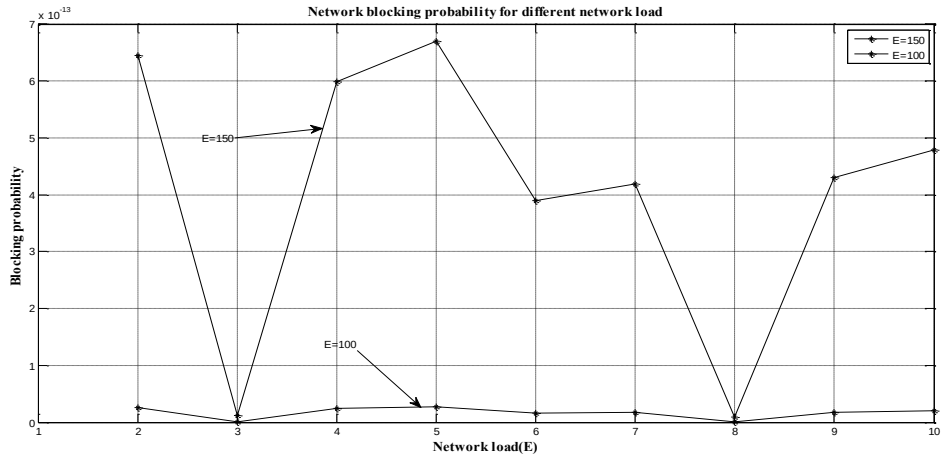


Figure 4.12: Node blocking probability of disjoint path with 8 wavelengths for disjoint path having different network loads ρ_{net} are 150E and 100E.

Similarly node 8 represents a maximum blocking probability of 0.15×10^{-14} for the network load ρ_{net} =100E. It supports 2 out of 57 of the possible routes having maximum blocking probability shown in fig.4.11b)

Figure 4.13 shows different number of wavelengths, when λ=8 and λ=16 the problem with the simulation resolution for the disjoint path can be viewed.

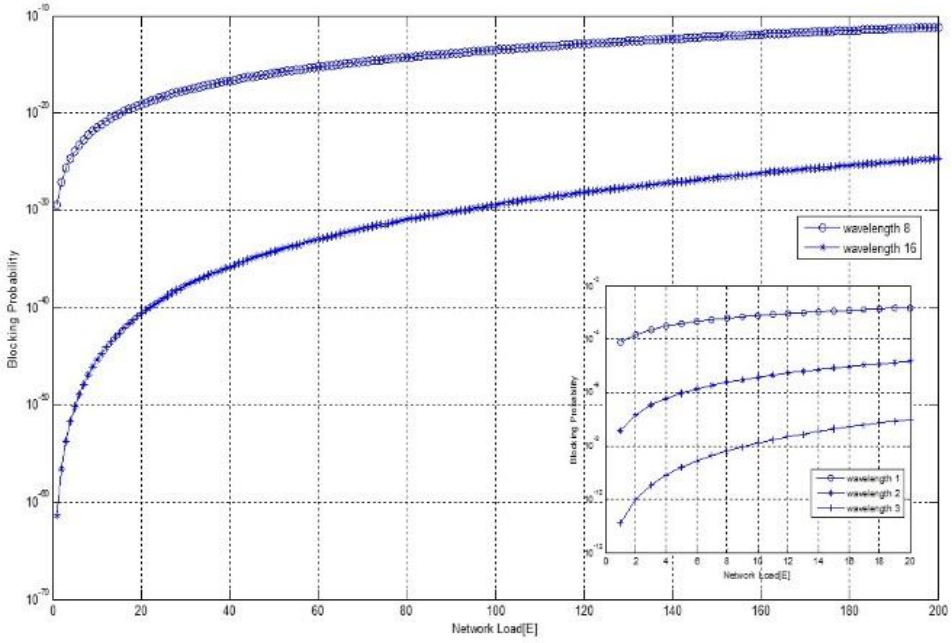


Figure 4.13. Network blocking of disjoint path probability.

4.4.3 Effect of network Traffic load with number of wavelengths for shortest path

The only one shortest path is available from the total number of available paths

1 2 0 0 0 0 0 0 0 0

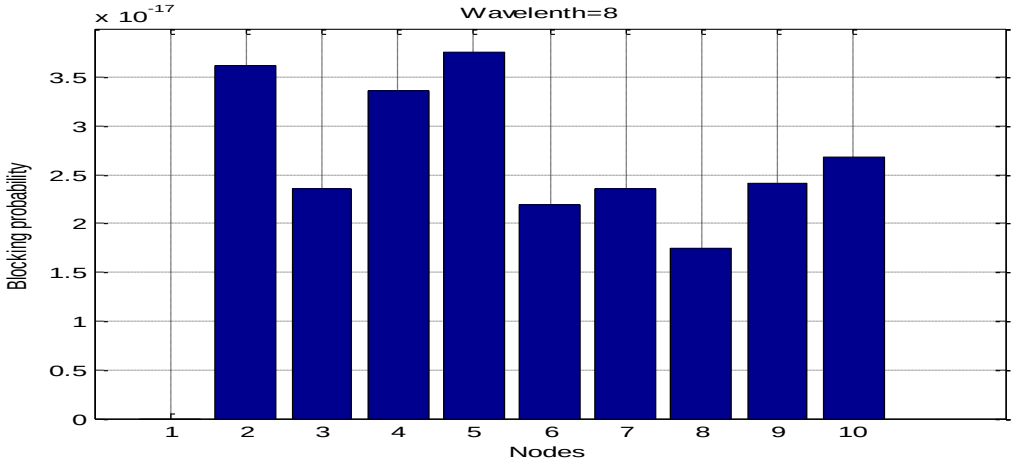
We know that the shortest path will be one for each source destination pair so no need to calculate the total number of shortest path and blocking probability for each link will be same for different wavelength which is given in the following table, as the shortest path for is only one so that the load matrix will be same for each route for the typical traffic load similarly for the blocking probability for each link having the same value for typical value of wavelength so we directly calculate blocking probability for each node which is as given below

Table 4.4: load matrix value for different traffic load

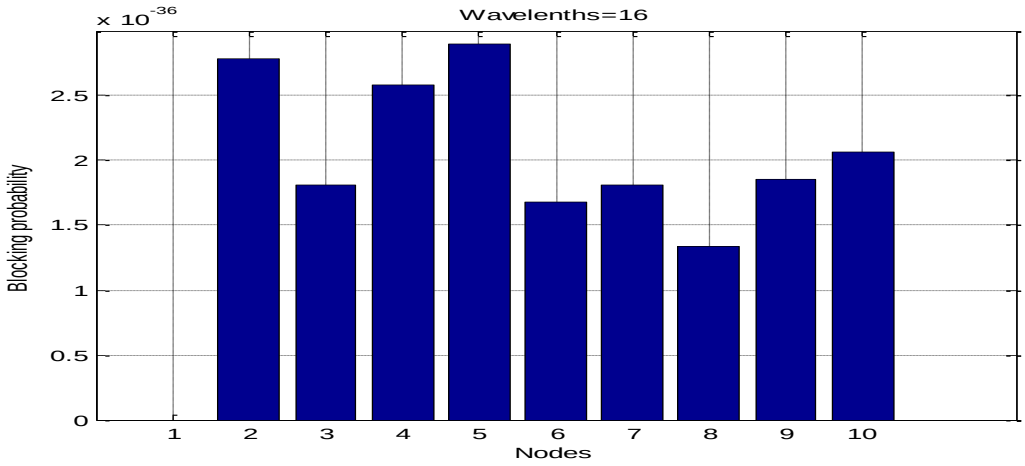
Traffic load	**Load matrix value**
150E	0.05
100E	0.0334
50E	0.0167

Table 4.5: Blocking probability for different wavelengths

Wavelength	Blocking probability
λ=8	9.4134×10^{-16}
λ=16	7.239×10^{-35}



a) Wavelength λ=8



b) Wavelength λ=16

Figure 4.14: Blocking probability of shortest path for each node for different wavelength a) λ=8 and b) λ=16

Figure 4.14 a) represents the results for the node BP for Shortest path with 8 wavelengths (λ=8) and with two values of network loads ρ_{net}. In this result node 8 represents a minimum BP of 1.7×10^{-17} for the network load ρ_{net} =150E. It supports 1 (i.e. only one shortest path) of the possible routes having BP. Resulting an average of Request will arrive at this node. Similarly node 8 represents a maximum blocking probability of 0.7×10^{-18} for the network load ρ_{net}=100E. It supports 1 out of 57 of the possible routes having minimum BP, shown in figure 4.14b)

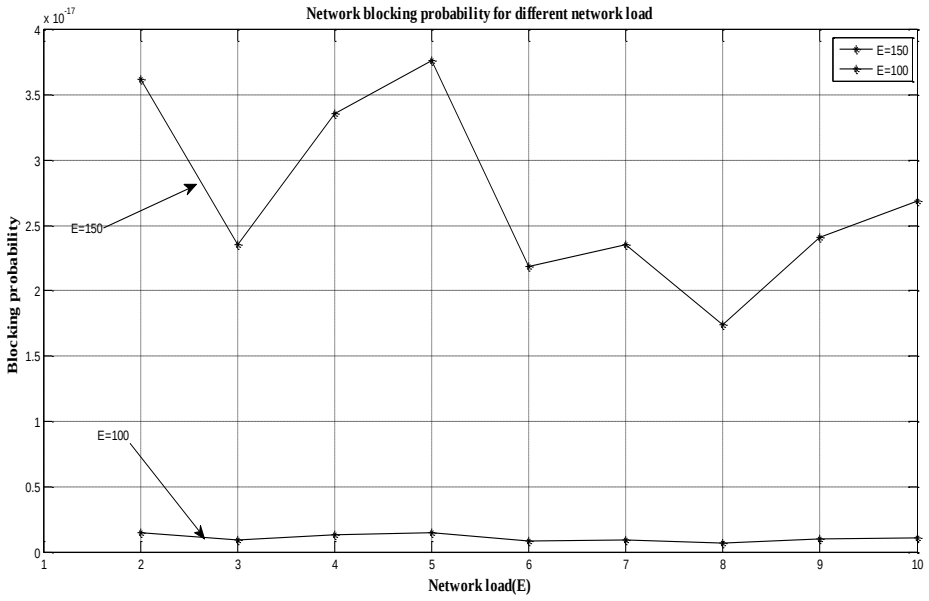


Figure 4.15 Node blocking probability with 8 wavelengths for shortest path having different network loads ρ_{net} 150E and 100E

Figure 4.16 shows different number of wavelengths, when λ=8 and λ=16 the problem with the simulation resolution for the shortest path can be viewed.

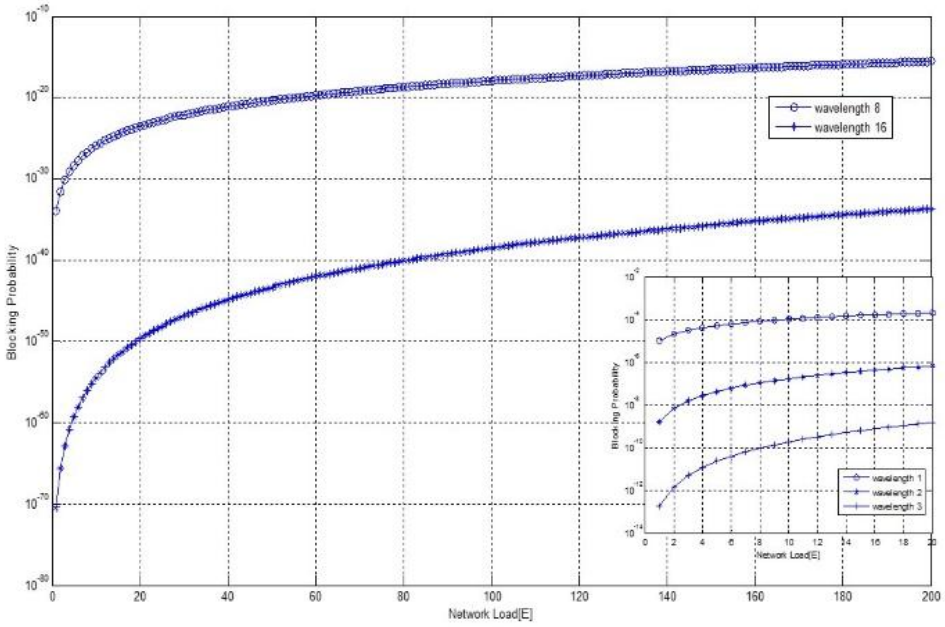


Figure 4.16: Network blocking probability of shortest path for different number of wavelengths.

5.

Conclusion and Future work

Conclusion

In WRON the BP is exactly computed. The number of wavelength optical network wavelength in the optical links assurance of the model for computing the blocking analysis which employs link/node dependence strategy. This technique provides very efficient results to estimate the BP for all possible disjoint and shortest optical network connections. From this results, it explains the blocking performance for all possible paths, disjoint paths and shortest paths, and we get the precise results. It is concluded that the best network probability is for the shortest path means it is having the least BP for different network loads and for different number of wavelengths.

Further research Problem

1. To implement Interactive Matrix Methodology (IMM) for calculating Blocking probability for various RWA algorithms and for number of topology.
2. Blocking probabilities per node can be estimated by this methodology, including the situations where each node and the links having multiple number of wavelengths.
3. Sparse placement of network resources can be used for IMM.
4. Also the grooming node technique is also implemented to improve the performance of the network.

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